# Advanced Propulsion Systems Demand Accurate Property Data

*As part of the NASA Space Launch Initiative's Next Generation Launch Technology Program, NASA and engine manufacturers are designing advanced rocket engines that will combust RP-1 fuel (RP-1 is rocket propellant used in first stage boosters.). While reliable thermophysical properties are essential for this purpose, present-day models are either based on a single pure component surrogate compound (with measurements limited to less than 100 ºC) or on estimation methods that are grounded in very limited data. NASA representatives cite a study which concluded that property uncertainties account for 70% of the uncertainty in a portion of the propulsion system design, and that the differences in RP-1 properties from different sources can amount to 5% to 60%. New measurements and models were needed to address this problem. NIST provided much of the property measurement and modeling in 2004, however, some important activities were completed during 2005 and are described below.*

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A gas chromatography - mass spectrometry – infrared spectrophotometry method was used to chemically characterize a sample of RP-1 supplied by NASA. As expected, our analysis showed that RP-1 is a complex liquid fuel that consists of significantly more than 100 components. A study of thermal decomposition kinetics for RP-1 as a function of temperature was made to avoid property measurements at temperatures where decomposition was excessive. The decomposition study was completed and published this year [1]. Measurements of the distillation curve of this complex fluid were done with a new advanced technique developed at NIST. The major novel aspects of the method feature temperature and volume measurements of lower uncertainty than is possible with conventional approaches, and a channel of data that provides the chemical composition of each distillate fraction. This composition measurement is done by sampling individual cuts on-the-fly during the measurement of the distillation curve [2]. Subsequently, any applicable analytical method can be applied to study the fraction. In the figure, we show the distillation curve for RP-1, along with chromatograms obtained with a flame ionization detector. We have also applied mass spectrometry and sulfur chemiluminescence detection to the analysis of distillate cuts. In addition to the added information content of the composition channel, the approach can be used as a diagnostic in the case of unexpected or spurious distillation curve results. In this respect, we were able to identify the important characteristics of an out-of-specification lot of RP-1, and explain the result in terms of distillate cut composition.

NIST researchers developed new measurements and models to address the industry concerns surrounding the accuracy of available thermophysical properties of RP-1 fuel.

***References:***

1. Andersen, P.C., Bruno, T.J., **Thermal decomposition kinetics of RP-1 rocket propellant**, *Ind. Eng. Chem. Res.*, 44(6), 1670-1676, 2005.
2. Bruno, T.J., **Method and apparatus for precision on-line sampling of distillate**, *Sep. Sci. Tech.*, 41(2), 309-314, 2006.

***Advanced distillation curve for RP-1, with the addition of a composition channel of data on a fraction by fraction basis.***